THE COMPARISON OF P/Tr AND K/T BOUNDARIES ON THE BASIS OF COSMIC SPHERULES FOUND IN HUNGARY.

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Introduction: The major mass extinctions of taxa, enhanced tectonics, sea level changes, and volcanic activity were taking place during both the Permo-Triassic (P/Tr) and Cretaceous-Tertiary (K/T) extinction levels [1,2]. We give here a brief summary of our analyses of cosmic spherules extracted from geologic samples found in Hungary in the P/Tr and close to the K/T boundaries. Moreover, we suggest a new stratigraphic method to establish a relationship between spherules and the conventional geologic and various other stratigraphic layers on the Earth and on other objects in the solar system.

P/Tr and K/T Differences: The uncertainties of time-scale and dating as well as the inherent limits of resolution of the time of extinctions of taxa are summarized by [3–5]. The range of uncertainty in the estimated age of the P/Tr boundary is about 20 m.y.; the error is not symmetrical about the 248 m.y. age given by [3]. There is a big difference between the P/Tr and K/T in the duration and in the uncertainty of dating. The duration of the K/T episode is much sharper: the extinction took place in about five distinct steps over a probable interval of about 2.0 to 2.5 m.y., extending from the middle-upper Maestrichtian boundary into the early Paleocene; the end of the Maestrichtian has been variously estimated at 65 to 66.4 m.y. [3,6]. Because interest has focused on the K/T mass extinctions and other events with a possible extraterrestrial cause, the record across the P/Tr boundary is too poor for detailed study. The cause of the end-Permian mass extinction appears to involve a tangled web rather than a single mechanism. Three phases can be identified during a longer interval [7]. This mass extinction is related to plenty of disciplines, such as paleobiology, paleoclimatology, paleoceanography, paleotectonics, paleovolcanic activity (continents, sea level changes, seafloor, gases, anoxia, CO_2), extinct and survived (or altered) taxa, etc. The sedimentary rock generally contains cosmic dust, volcanic ash, skeletons, fossils, etc. The microspherules in P/Tr bedded chert were estimated by PIXE analysis by [8]. They found that (1) the origin of microspherules as inferred from the Ti/Fe and Cr/Fe ratios is clearly extraterrestrial; (2) their average chemical composition is quite similar to the magnetic components of carbonaceous chondrite; (3) most of the spherules are hollow and are smaller than those obtained from recent drill core samples; and (4) the number of microspherules increases sharply in the Triassic-Jurassic boundary layer. They concluded that this possible evidence seems to support the molecular cloud hypothesis, i.e., that the solar system encountered an interstellar molecular cloud in the past. Connecting the strange chemical composition changes of gases (anoxia) in the atmosphere and sea during the P/Tr episode, some authors consider the consequences of supernova explosions on the atmosphere of the Earth. Recent models emphasize volcanism, global tectonism, enormous volcanic activities (flood basalt; [9,10]), sea-floor volcanism, global climatic changes as well as possible extraterrestrial impacts. It is concluded [11] that the microspherules found in the P/Tr boundary cannot be associated with impact events. However, recently during the annual meeting of the Geological Society of America, paleontologist G. Retallack presented pictures of microscopic quartz grains that he claims are the "first unequivocal evidence of an impact" [12]. It is obvious that the P/Tr boundary is a consequence of a complexity of various events. However, both the P/Tr and K/T events belong to the same cosmic cycle of periodicity, the so-called shorter Holmes cycle with an estimated period of around 30 m.y. [13,14]. There are lots of arguments that the K/T boundary is related to violent cosmic impact events (see, e.g., the papers reviewing K/T-related topics, mainly impact craters, dating, anomalies of Ir and other elements, and global phenomena among others by [15–21]. However, there are some difficulties associated with the Ir anomalies found in the K/T: there are arguments that this could have originated from enormous volcanic activity [22]. Further problems with the impact-related extinction events in the K/T were discussed by [23], who concluded that it looks as though a bolide impact alone cannot explain the whole of the biotic crisis at the end of the Cretaceous. However, it seems to be that the impact hypothesis is confirmed according to the discovery of evidence of the relicts and traces of a huge impact event in the India-Seychelles rift margin [20], called "Shiva Crater," after [14], with sizes of 600 × 450 km. Even this crater can be linked to Chicxulub genetically: Both craters might have originated when two fragments from a larger meteorite crashed on a rotating Earth and, due to the geometry and rotational phase, these craters are in antipodal position [20]. The example of the crash of fragments of comet Shoemaker-Levy 9 on Jupiter provides the analogy the giant "drumfire" on the Earth in the K/T period.

New Results—Comparison of Spherules: We have confirmed that the P/Tr boundary is related to cosmic events because the spherules that have been collected in the Bükk mountain, Hungary, show evidence of interstellar origin rather than the results of high-velocity impacts of cosmic bodies [24]. The similarities are evident between our small spherules and those reported by [8]. We argue that the consequences of the explosion of a nearby supernova could be the source of the P/Tr spherules and the other dramatic atmospheric changes and other terrestrial paleoenvironmental effects [25] when the solar system encountered the shock front. According to the chemical and morphological analyses of the spherules in the geological samples collected in Hungary we report evidence that the spherules have been found (1) in the upper Cretaceous formations [26], as well as (2) the extraterrestrial magnetic spherules in the Senonian alluvial sediments of the Southern Bakony mountains [27] are impacts rather than volcanic origin associated with the Cretaceous-Tertiary (K/T) events. Thus the P/Tr and K/T events show differences in the nature and origin of related cosmic spherules: In the P/Tr boundary the spherules that dominated probably have an interstellar origin (or the cosmic dust and the possible impactor bodies continued interstellar material that have encountered our planet), while in the K/T the spherules were created during violent impact events. However, the occurrence of some impact events cannot be excluded in the P/Tr [12], but the dominance of impact events is less significant.

A Retrospective View: There is evidence from the analyses of lunar soil samples that impact events could be identified in the history of the Moon's surface according to the analysis of glassy spherules within a size of <200 µm [28]. There are characteristic differences between spherules with volcanic and impact origin. Volcanic glasses are larger in size (on average) ~1000-µm range, while impact spherules are in the 0.1–10-µm range. Volcanic spherules represent those basaltic melts that originated in the lunar mantle. Volcanic spherules can be arranged according to their Ti content, from green (A-15) glasses, through yellow (A-15, and A-17) and orange (A-17) glasses, to red (A-15) glass. Impact spherules represent both residuals of quick volatile evaporation (HASP: High Al, Si Poor) and quickly condensed volatile-rich (VRAP) types [28]. Impact spherules can be characterized by the different degrees of volatile loss. Extreme volatile losses left the most refractory constituent of the mineral that had originally been present in the rocks or soil. The radiometric ages were measured only for 74220-type volcanic glass spherules among Apollo 17 samples; however, their age is rather old (3.48–3.66 m.y., obtained earlier by several authors [29]). No age determinations have been carried out on impact glasses [28].

New Perspective: The study of spherules is a new tool that allows the dating of impact chronology in the Earth's environment by studying the samples in order to compare them with the various stratigraphic methods. In perspective, *spherula stratigraphy* may be developed as an *independent new tool* to study solar system bodies oat finer temporal resolution.

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